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MODELLING OF THE VARIOUS FLEXIBILITIES IN A FLEXIBLE MANUFACTURING SYSTEM

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ABSTRACT

The manufacturing organizations adopt Flexible Manufacturing Systems to meet the challenges imposed by today's volatile market standards. An FMS is designed to combine the efficiency of a mass production line and the flexibility of a job shop to produce a variety of products on a group of machines. Flexibility is a key factor in a flexible manufacturing system performance. Despite the advantages offered, the implementation of FMS has not been very popular as it is very difficult to quantify the factors favouring FMS implementation. Therefore an attempt has been made in the present work to identify and categorize various flexibility factors influenced by the implementation of FMS in a firm further these factors are quantitatively analyzed to find their inhibiting strength using Graph Theory Approach (GTA).

KEYWORDS: FMS, Flexibility, Manufacturing, GTA.

1. INTRODUCTION

In today's competitive global market, manufacturers have to modify their operations to ensure a better and faster response to needs of customers (Liorens et al., 2005). The primary goal of any manufacturing industry is to achieve a high level of productivity and flexibility which can only he done in a computer integrated manufacturing environment.

A flexible manufacturing system (FMS) is an integrated computer-controlled configuration in which there is some amount of flexibility that allows the system to react in the case of changes, whether predicted or unpredicted. FMS consists of three main systems. The work machines which are often automated CNC machines are connected by a material handling system(MHS) to optimize parts flow and the central control computer which controls material movements and machine flow.

An FMS is modeled as a collection of workstations and automated guided vehicles (AGV). It is designed to increase system utilization and throughput of system and for reducing average work in process inventories and many factors affects both system utilization and throughput of system.

2. LITERATURE REVIEW

Flexible Manufacturing Systems have been developed with the hope that they will be able to tackle new challenges like cost, quality, improved delivery speed and to operate to be more flexible in their operations and to satisfy different market segments (Jain and Raj, 2016). An FMS is viewed as a crucial step towards the concept of the 'factory of the future' (Suri, 1985).

Panday, R et al. (2016) evaluate the performance of a flexible manufacturing system (FMS) in a manufacturing industry. In this paper, authors have made an attempt to overcome the impact of uncertainties such as machine breakdowns, deadlocks, system implementation.

Kahtani, M et al. (2014) evaluate the effect of different input factors, including layout, MHS configuration on FMS performance measured by total production cost, total flow time and throughput. It analyses the cost benefit between various layouts with a hypothetical case.

Kumar, B et al. (2015) measures & analyses the performance measure of FMS using Flexsim Software. Also Bottleneck technique is also applied for verification & comparison of the simulation result.

So, the adoption of this flexible production technology is luring manufacturing managers worldwide. Most manufacturing organisations want to adapt to this highly attractive technology in a hurry to gain a competitive edge without caring for the suicidal repercussions of something acclaimed as the ultimate weapon of production technology (Raj et al., 2010b). FMS requires huge capital investment and is a complex system. Though FMS provides a lot of strategic and tactical benefits, yet all of these may not be possible with all installations. A manufacturing manager should know what are the specific benefits he is expecting from the FMS installation and what is the time span within which these benefits start coming in (Dixit and Raj, 2016). So it becomes necessary to enlist the factors affecting flexibility of FMS installation and to further categorize them to quantify their inhibiting strengths.

2.1 Identification and Categorisation of the various factors

On the basis of literature review and discussions with experienced manufacturing managers and academicians, it has been found that a number of flexibility factors are affected by the FMS installation in any firm, these are broadly grouped into the following categories:

Table 1. List of considered Flexibility factors

Sr. No.	Flexibility	Factors affecting flexibility
1.	Product flexibility (F1)	New product handling capacity Flexibility of fixtures Design flexibility of the production system
2.	Machine flexibility (F2)	Better machine utilization Ability to produce a variety of products Setup time reduction Automation
3.	Production flexibility (F3)	Reconfiguration of machine tools Minimization of scrap Combined multi operations Improve response speed Reduced inventories

3. METHODOLOGY

3. 1 Graph Theoretic Approach (GTA)

GTA is a powerful tool that can be applied to diverse fields. It synthesizes the inter-relationship among different variables or subsystems and provides a synthetic score for the entire system. This technique has been used widely by the researchers in the past because of its inherent simplicity.

3.1.1 General Methodology of Graph Theoretic approach

General methodology of graph theory and matrix method addressed by all the authors for analyzing, evaluation and selection of various manufacturing systems and processes using is given below:

1. Identifying the factors (attributes) which affect the objective of the manufacturing, System/process considered. They are identified based on the shop floor data, experience of the persons involved in the operation, maintenance and design.

2. After identifying the contributing factors, their effect/ disaffect/ relative importance are Considered.

3. The digraph model is constructed by considering attributes as nodes and relative Importance of attributes over the objective as edges.

4. Permanent matrix is developed for the digraph which is a one-to-one representation, in which diagonal elements represent the contribution of attributes (events) and the off diagonal elements represent the relative importance among the attributes.

5. Obtaining the permanent function from the permanent matrix to characterize the manufacturing process/system.

6. Arriving (assigning) the quantitative value of the attributes and their relative importance.

7. Calculating the numerical indices by substituting the value of attributes and their relative importance in the permanent function.

8. Obtaining the numerical indices for various system/ process alternatives. Based on the numerical index values, the processes/systems are arranged in ascending order.

9. Selecting the suitable process/system for which numerical index is higher.

Table 2. The inheritance of FMS flexibility factors

Sr. No.	Qualitative measure of Flexibility Factors	Assigned value of Flexibility Factors
1	Exceptionally low	1
2	Extremely low	2
3	Very low	3
4	Below average	4
5	Average	5
6	Above average	6
7	High	7
8	Very high	8
9	Extremely high	9
10	Exceptionally high	10

Table 3. The values of interdependence of FMS flexibility factors

Sr. No.	Qualitative measure of interdependence of Factors	Assigned value
1	Very strong	5
2	Strong	4
3	Medium	3
4	Weak	2
5	Very weak	1

3.1.2 Digraph representation and matrix formation

The digraph for the factors selected in table no. 1 is shown in the figure 11.

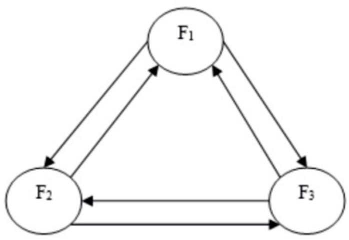

Fig.11. FMS Flexibility Factors Digraph

The FMS Flexibility matrix for the FMS flexibility digraph with three categories of influencing factors shown in figure 1 is written as:

$$F^* = \begin{array}{c} \text{Factors} \\ F_1 \\ F_2 \\ F_3 \end{array} \begin{array}{c} \begin{array}{ccc} F_1 & F_2 & F_3 \end{array} \\ \begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix} \end{array}$$

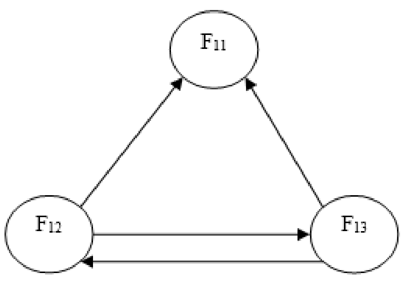

Fig.12. Digraph for Product flexibility Factors

Matrix for Product flexibility Factors:

$$F_1^* = \begin{array}{c} \text{Factors} \\ F_{11} \\ F_{12} \\ F_{13} \end{array} \begin{array}{c} \begin{array}{ccc} F_{11} & F_{12} & F_{13} \end{array} \\ \begin{pmatrix} 8 & 0 & 0 \\ 4 & 9 & 3 \\ 3 & 3 & 7 \end{pmatrix} \end{array}$$

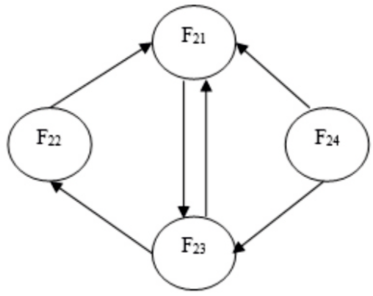

Fig.13. Digraph for Machine Flexibility Factors

Matrix for Machine flexibility Factors:

$$F_2^* = \begin{array}{c} \\ F_{21} \\ F_{22} \\ F_{23} \\ F_{24} \end{array} \begin{array}{c} \begin{array}{cccc} F_{21} & F_{22} & F_{23} & F_{24} \end{array} \\ \begin{pmatrix} 9 & 0 & 3 & 0 \\ 4 & 7 & 0 & 0 \\ 5 & 3 & 8 & 0 \\ 4 & 0 & 3 & 6 \end{pmatrix} \end{array}$$

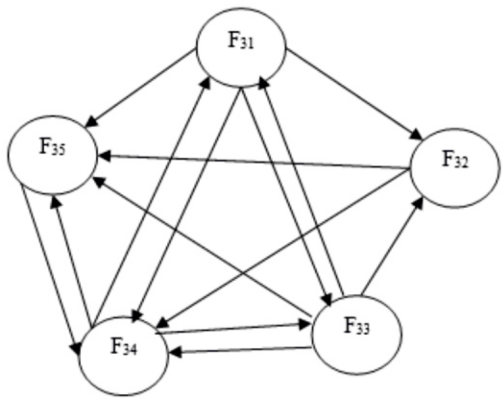

Fig.13. Digraph for Production flexibility Factors

Matrix for Production flexibility Factors:

$$F_3^* = \begin{array}{c} \\ F_{31} \\ F_{32} \\ F_{33} \\ F_{34} \\ F_{35} \end{array} \begin{array}{c} \begin{array}{ccccc} F_{31} & F_{32} & F_{33} & F_{34} & F_{35} \end{array} \\ \begin{pmatrix} 9 & 3 & 4 & 2 & 3 \\ 0 & 8 & 0 & 3 & 3 \\ 3 & 4 & 7 & 4 & 3 \\ 2 & 0 & 3 & 9 & 4 \\ 0 & 0 & 0 & 3 & 7 \end{pmatrix} \end{array}$$

The value of permanent function for each category of factors is calculated e.g. the value of permanent function comes out to be:

Per F_1^* = 576, Per F_2^* = 3870, Per F_3^* = 65862

The values of permanent function at sub factor level are taken as the diagonal elements of flexibility matrix at the system level and assigning the values of interdependence we have

$$F^* = \begin{array}{c} \\ F_1 \\ F_2 \\ F_3 \end{array} \begin{array}{c} \begin{array}{ccc} F_1 & F_2 & F_3 \end{array} \\ \begin{pmatrix} 576 & 3 & 4 \\ 3 & 3870 & 4 \\ 4 & 4 & 65862 \end{pmatrix} \end{array}$$

The value of permanent function at the system level is evaluated and it comes out to be

Per F^*= 1.46815×10^{11}.

This value of Per $F^* = 1.46815 \times 10^{11}$ indicates the influence of FMS on the flexibility of any firm and is the quantification or the mathematical value showing how much is the flexibility of FMS in any firm is influenced by the various governing factors.

Further the hypothetical extreme values of permanent function are calculated. These are the maximum and minimum values of permanent function and indicate the scope of improvement at overall and subsystem level. The flexibility index is maximum or minimum when the inheritance of all the factors is maximum or minimum respectively. The inheritance of each factor depends on its sub factors and the value of Permanent function will be maximum when the inheritance of sub factors is maximum. For example, the value of Per F_1* for the first category i.e. product flexibility is maximum when the inheritance of all its sub factors is maximum, i.e. 9, as per table 2. Hence the flexibility factors matrix for this category may be rewritten as:

$$F_1^* = \begin{array}{c} \\ F_{11} \\ F_{12} \\ F_{13} \end{array} \begin{array}{c} \begin{array}{ccc} F_{11} & F_{12} & F_{13} \end{array} \\ \begin{pmatrix} 9 & 0 & 0 \\ 4 & 9 & 3 \\ 3 & 3 & 9 \end{pmatrix} \end{array}$$

The maximum value of Per F_1* for the first category is 810.

The value of Per F_1* of product flexibility factors is minimum when the inheritance of all its sub factors is minimum, i.e. 1 as per table 2. Hence the FMS flexibility matrix for this category may be rewritten as:

$$F_1^* = \begin{array}{c} \\ F_{11} \\ F_{12} \\ F_{13} \end{array} \begin{array}{c} \begin{array}{ccc} F_{11} & F_{12} & F_{13} \end{array} \\ \begin{pmatrix} 1 & 0 & 0 \\ 4 & 1 & 3 \\ 3 & 3 & 1 \end{pmatrix} \end{array}$$

The minimum value of Per P_1* for the first category is 10.

Similarly the maximum and minimum values for each factor are calculated and is presented in table 4.

Table 4. Maximum and minimum values of Flexibility index

Permanent function at Sub factor level	Maximum Value	Current Value	Minimum Value
F_1	810	576	10
F_2	8100	3870	52
F_3	106533	65862	1357
F	6.98964×10^{11}	1.46815×10^{11}	718941

The extreme limits of Permanent function indicate its range, which can be utilized in finding the influence of FMS on the flexibility of the firm. There is maximum scope for the improvement in flexibility when the value of permanent function is near its minimum value and the scope is minimum or maximum utilization has been made when the permanent function is near its maximum value.

4. RESULTS & CONCLUSION

In this project work I have tried to identify and define the various types of flexibilities in a flexible manufacturing system. These flexibilities are further studied and their governing factors are identified which affects the various flexibilities in FMS. All these factors are discussed briefly in this file.

As a conclusion of this project work, an attempt has been made in this study to identify the various flexibilities affected by the FMS, they are grouped into sub factors. A logical procedure based on GTA methodology is used to focus on the flexibility of a firm in a FMS environment. A numerical index is proposed to evaluate these flexibility factors which ranks them so that the practicing managers can have better focus.

Permanent function at Sub factor level	Maximum Value	Current Value	Minimum Value
F_1	810	576	10
F_2	8100	3870	52
F_3	106533	65862	1357
F	6.98964×10^{11}	1.46815×10^{11}	718941

The above table shows the current value as well as the maximum and minimum possible values of permanent function at sub factor level. The extreme limits of Permanent function indicate its range, which can be utilized in finding the influence of FMS on the flexibility of the firm. There is maximum scope for the improvement in flexibility when the value of permanent function is near its minimum value and the scope is minimum or maximum utilization has been made when the permanent function is near its maximum value.

5. LIMITATIONS AND FUTURE SCOPE

5.1 Limitations

As with any project work this study is also associated with some limitations:

- The present study applies GTA technique which gives a big numerical value of Permanent function. In the present case, it is 1.46815x1011, which may appear to be an odd figure for practical purposes.
- The development of an equation for the permanent function becomes difficult because of combinatorial approach, especially when there are a large number of factors. This requires computer software to solve the same.
- The inheritance of sub factors and their interdependencies are based on the opinions of experts, which may be biased in some cases.

5.2 Future Scope

- The permanent function value as proposed in this approach, provide a numerical value for any industry. By knowing the values of permanent function of different industries, their manufacturing systems can be compared for flexibility and also the scope for the improvement can be highlighted.
- The approach can be further extended to calculate the permanent function and hence numerical indexes at each sub factor level also.
- The proposed methodology can be extended to any type of variables in FMS.

REFERENCES:

1. Ali, M. and Wadhwa, S. (2005) 'Performance analysis of partial flexible manufacturing systems', Global Journal of Flexible Systems Management, Vol. 6, No.1, pp. 9-19.
2. Bengtsson, J. and Olhager, J. (2002) 'Valuation of product-mix flexibility using real options', International Journal of Production Economics, Vol. 78, No.1, pp.13-28.
3. Buyurgan, N., Saygin, C., & Kilic, S. E. (2004) 'Tool allocation in flexible manufacturing systems with tool alternatives', Robotics and Computer-Integrated Manufacturing, Vol. 20, No.4, pp. 341-349.
4. Jain, V., Raj, T. (2013) 'Ranking of flexibility in flexible manufacturing system by using a combined multiple attribute decision making method' Global journal of flexible system management, Vol. 14, No. 3, pp. 125-141.
5. Raj, T., Shankar, R., Suhaib, M. and Khan, R. (2007) 'Some dimensions of flexibilities in FMS', Proceedings of GLOGIFT, Vol. 7, pp.328-334.
6. Attri, R., Grover, S., Dev, N. and Kumar, D. (2013) 'Analysis of barriers of total productive maintenance (TPM), International Journal of Systems Assurance Engineering and Management, Vol. 4, pp. 365-377.
7. Raj, T., Shankar, R., Suhaib, M.(2007) 'A review of some issues and identification of some barriers in the implementation of FMS' International Journal of Flexible Manufacturing System, Vol. 19,No. 1, pp. 1-40.
8. Raj, T., Attri, R., Jain, V.(2012) 'Modelling the factors affecting flexibility in FMS' International Journal of Industrial and Systems Engineering, Vol. 11, No. 4, pp. 350-374.
9. Panday, R., Sharma, N. and Singh, A. Tomar (2016), 'Performance Evaluation of Flexible Manufacturing System (FMS)in Manufacturing Industries', Imperial Journal of Interdisciplinary Research (IJIR), Vol. 2, No. 3.
10. Nirmal, N., Dahiya, N., 'Material Handling in Flexible Manufacturing System', International Journal of Computer Science and Management Studies, Vol. 11, pp 40-44.